VERSION WITH MARKINGS TO SHOW CHANGES MADE

IN THE SPECIFICATION:

The paragraph beginning on page 8, line 3 has been replaced with the following paragraph. Note that the only change here is the insertion of a space before the sentence beginning with the phrase "Fast fading...":

Loss due to slow fading includes shadowing due to clutter blockage (sometimes included in Lp). Fast fading is composed of multipath reflections which cause: 1) delay spread; 2) random phase shift or Rayleigh fading; and 3) random frequency modulation due to different Doppler shifts on different paths.

The paragraph beginning on page 10, line 3 through page 10, line 20 has been replaced with the following paragraphs:

It is an objective of the present invention to provide a system and method for to wireless telecommunication systems for accurately locating people and/or objects in a cost effective manner. Additionally, it is an objective of the present invention to provide such location capabilities using the measurements from wireless signals communicated between mobile stations and a network of base stations, wherein the same communication standard or protocol is utilized for location as is used by the network of base stations for providing wireless communications with mobile stations for other purposes such as voice communication and/or visual communication (such as text paging, graphical or video communications). Related objectives for <u>various embodiments of</u> the present invention include providing a system and method that:

(1.1) can be readily incorporated into existing commercial wireless telephony systems with few, if any, modifications of a typical telephony wireless infrastructure;

(1.2) can use the native electronics of typical commercially available<u>, or likely to be available,</u> telephony wireless mobile stations (e.g., handsets) as location devices;

(1.3) can be used for effectively locating people and/or objects wherein there are few (if any) line-of-sight wireless receivers for receiving location signals from a mobile station (herein also denoted MS);

(1.4) can be used not only for decreasing location determining difficulties due to multipath phenomena but in fact uses such multipath for providing more accurate location estimates;

(1.5) can be used for integrating a wide variety of location techniques in a straight-forward manner; [and]

(1.6) can substantially automatically adapt and/or (re)train and/or (re)calibrate itself according to changes in the environment and/or terrain of a geographical area where the present invention is utilized;

(1.7) can utilize a plurality of wireless location estimators based on different wireless location technologies (e.g., GPS location techniques, terrestrial base station signal timing techniques for triangulation and/or trilateration, wireless signal angle of arrival location techniques, techniques for determining a wireless location within a building, techniques for determining a mobile station location using wireless location data collected from the wireless coverage area for, e.g., location techniques using base station signal coverage areas, signal pattern matching location techniques and/or stochastic techniques), wherein each such estimator may be activated independently of one another, whenever suitable data is provided thereto and/or certain conditions, e.g., specific to the estimator are met;

(1.8) can provide a common interface module from which a plurality of the location estimators can be activated and/or provided with input;

(1.9) provides resulting mobile station location estimates to location requesting applications (e.g., for 911 emergency, the fire or police departments, taxi services, vehicle location, etc.) via an output gateway, wherein this gateway:

(a) routes the mobile station location estimates to the appropriate location application(s) via a communications network such as a wireless network, a public switched telephone network, a short messaging service (SMS), and the Internet,

(b) determines the location granularity and representation desired by each location application requesting a location of a mobile station, and/or

(c) enhances the received location estimates by, e.g., performing additional processing such as "snap to street" functions for mobile stations known to reside in a vehicle.

The paragraph beginning on page 11, line 15 has been replaced with the following paragraph:

(3.3) The term, "infrastructure", denotes the network of telephony communication services, and more particularly, that portion of such a network that receives and processes wireless communications with

wireless mobile stations. In particular, this infrastructure includes telephony wireless base stations (BS) such as those for radio mobile communication systems based on CDMA, AMPS, NAMPS, TDMA, and GSM wherein the base stations provide a network of cooperative communication channels with an air interface with the MS, and a conventional telecommunications interface with a Mobile Switch Center (MSC). Thus, an MS user within an area serviced by the base stations may be provided with wireless communication throughout the area by user transparent communication transfers (i.e., "handoffs") between the user's MS and these base stations in order to maintain effective telephony service. The mobile switch center (MSC) provides communications and control connectivity among base stations and the public telephone network 124.

The paragraph beginning on page 12, line 6 has been replaced with the following paragraphs:

The present invention relates to a wireless mobile station location system, and in particular, various subsystems related thereto such as a wireless location gateway, and the combining or hybriding of a plurality of wireless location techniques.

Regarding a wireless location gateway, this term refers to a communications network node whereat a plurality of location requests are received for locating various mobile stations from various sources (e.g., for E911 requests, for stolen vehicle location, for tracking of vehicles traveling cross country, etc.), and for each such request and the corresponding mobile station to be located, this node: (a) activates one or more wireless location estimators for locating the mobile station, (b) receives one or more location estimates of the mobile station from the location estimators, and (c) transmits a resulting location estimate(s) to, e.g., an application which made the request. Moreover, such a gateway typically will likely activate location estimators according to the particulars of each individual wireless location request, e.g., the availability of input data needed by particular location estimators. Additionally, such a gateway will typically have sufficiently well defined uniform interfaces so that such location estimators can be added and/or deleted to, e.g., provide different location estimators for performing wireless location different coverage areas.

The present invention encompasses such wireless location gateways. Thus, for locating an identified mobile station, the location gateway embodiments of the present invention may activate one or more of a plurality of location estimators depending on, e.g., (a) the availability of particular types of wireless location data for locating the mobile station, and (b) the location estimators accessable by the location gateway. Moreover, a plurality of location estimators may

be activated for locating the mobile station in a single location, or different ones of such location estimators may be activated to locate the mobile station at different locations. Moreover, the location gateway of the present invention may have incorporated therein one or more of the location estimators, and/or may access geographically distributed location estimators via requests through a communications network such as the Internet.

In particular, the location gateway of the present invention may access, in various instances of locating mobile stations, various location estimators that utilize one or more of the following wireless location techniques:

(a) A GPS location technique such as, e.g., one of the GPS location techniques as described in the Background section hereinabove;

(b) A technique for computing a mobile station location that is dependent upon geographical offsets of the mobile station from one or more terrestrial transceivers (e.g., base stations of a commercial radio service provider). Such offsets may be determined from signal time delays between such transceivers and the mobile station, such as by time of arrival (TOA) and/or time difference of arrival (TDOA) techniques as is discussed further hereinbelow. Moreover, such offsets may be determined using both the forward and reverse wireless signal timing measurements of transmissions between the mobile station and such terrestrial transceivers. Additionally, such offsets may be directional offsets, wherein a direction is determined from such a transceiver to the mobile station;

(c) Various wireless signal pattern matching, associative, and/or stochastic techniques for performing comparisons and/or using a learned association between:

(i) characteristics of wireless signals communicated between a mobile station to be located and a network of wireless transceivers (e.g., base stations), and

(ii) previously obtained sets of characteristics of wireless signals (from each of a plurality of locations), wherein each set was communicated, e.g., between a network of transceivers (e.g., the fixed location base stations of a commercial radio service

provider), and, some one of the mobile stations available for communicating with the network;

(d) Indoor location techniques using a distributed antenna system;

(e) Techniques for locating a mobile station, wherein, e.g., wireless coverage areas of individual fixed location transceivers (e.g., fixed location base stations) are utilized for determining the mobile station's location (e.g., intersecting such coverage areas for determining a location);

(f) Location techniques that use communications from low power, low functionality base stations (denoted "location base stations"); and

(g) Any other location techniques that may be deemed worthwhile to incorporate into an embodiment of the present invention.

Accordingly, some embodiments of the present invention may be viewed as platforms for integrating wireless location techniques in that wireless location computational models (denoted "first order models" or "FOMs" hereinbelow) may be added and/or deleted from such embodiments of the invention without changing the interface to further downstream processes. That is, one aspect of the invention is the specification of a common data interface between such computational models and subsequent location processing such as processes for combining of location estimates, tracking mobile stations, and/or outputting location estimates to location requesting applications.

Moreover, it should be noted that the present invention also encompasses various hybrid approaches to wireless location, wherein various combinations of two or more of the location techniques (a) through (g) immediately above may be used in locating a mobile station at substantially a single location. Thus, location information may be obtained from a plurality of the above location techniques for locating a mobile station, and the output from such techniques can be synergistically used for deriving therefrom an enhanced location estimate of the mobile station.

It is a further aspect of the present invention that it may be used to wirelessly locate a mobile station: (a) from which a 911 emergency call is performed, (b) for tracking a mobile station (e.g., a truck traveling across country), (c) for routing a mobile station, and (d) locating people and/or animals, including applications for confinement to (and/or exclusion from) certain areas.

It is a further aspect of the present invention that it [In particular, such a wireless mobile station location system] may be decomposed into: (i) a first low level wireless signal processing subsystem for receiving, organizing and conditioning low level wireless signal measurements from a network of base stations cooperatively linked for providing wireless communications with mobile stations (MSs); and (ii) a second high level signal processing subsystem for performing high level data processing for providing most likelihood location estimates for mobile stations.

The paragraph beginning on page 12, line 11 has been replaced with the following paragraph:

Thus[More precisely], the present invention may be considered as [is]a novel signal processor that includes at least the functionality for the high signal processing subsystem mentioned hereinabove. Accordingly, assuming an appropriate ensemble of wireless signal measurements characterizing the wireless signal communications between a particular MS and a networked wireless base station infrastructure have been received and appropriately filtered of noise and transitory values (such as by an embodiment of the low level signal processing subsystem disclosed in a copending PCT patent application PCT/US97/15933 titled, "Wireless Location Using A Plurality of Commercial Network Infrastructures," by F. W. LeBlanc et al.,[and the present applicant(s); this copending patent application] filed September 8, 1997 from which U.S. Patent 6,236,365, filed July 8, 1999 is the U.S. national counterpart; these two references being herein fully incorporated by reference), the present invention uses the output from such a low level signal processing system for determining a most likely location estimate of an MS.

The paragraph beginning on page 12, line 19 (and ending on this same line 19) has been replaced with the following paragraph:

That is, once the following steps are appropriately performed (e.g., by the LeBlanc [copending application] U.S. Patent 6,236,365):

The paragraph beginning on page 12, line 28 has been replaced with the following paragraph:

(4.3) providing the composite signal characteristic values to one or more MS location hypothesizing computational models (also denoted herein as "first order models" and also "location estimating models"), wherein each such model subsequently determines one or more initial estimates of the location of the target MS based on, for example, the signal processing techniques 2.1 through 2.3 above.

Moreover, each of the models output MS location estimates having substantially identical data structures (each such data structure denoted a "location hypothesis"). Additionally, each location hypothesis may also include[s] a confidence value indicating the likelihood or probability that the target MS whose location is desired resides in a corresponding location estimate for the target MS;

The paragraph beginning on page 13, line 14 has been replaced with the following paragraph:

Referring now to (4.3) above, the filtered and aggregated wireless signal characteristic values are provided to a number of location hypothesizing models (denoted First Order Models, or FOMs), each of which yields a location estimate or location hypothesis related to the location of the target MS. In particular, there are location hypotheses for both providing estimates of where the target MS is likely to be and where the target MS is not likely to be. Moreover, it is an aspect of the present invention that confidence values of the location hypotheses are provided as a continuous range of real numbers from, e.g., -1 to 1, wherein the most unlikely areas for locating the target MS are given a confidence value of -1, and the most likely areas for locating the target MS are given a confidence value of 1. That is, confidence values that are larger indicate a higher likelihood that the target MS is in the corresponding MS estimated area, wherein [1] -1 indicates that the target MS is absolutely NOT in the estimated area, 0 indicates a substantially neutral or unknown likelihood of the target MS being in the corresponding estimated area, and 1 indicates that the target MS is absolutely within the corresponding estimated area.

The paragraph beginning on page 15, line 22 has been replaced with the following paragraph:

It is a further aspect of the present invention that the personal communication system (PCS) infrastructures currently being developed by telecommunication providers offer an appropriate localized infrastructure base upon which to build various personal location systems (PLS) employing the present invention and/or utilizing the techniques disclosed herein. In particular, the present invention is especially suitable for the location of people and/or objects using code division multiple access (CDMA) wireless infrastructures, although other wireless infrastructures, such as, time division multiple access (TDMA) infrastructures and GSM are also contemplated. Note that CDMA personal communications systems are described in the Telephone Industries Association standard IS-95, for frequencies below 1 GHz, and in the Wideband Spread- Spectrum Digital Cellular System Dual-Mode Mobile Station-Base Station Compatibility Standard, for frequencies in the 1.8-1.9 GHz frequency bands, both of which are incorporated herein by reference. Furthermore, CDMA general principles have also been described, for

example, in U. S. Patent 5,109,390, to Gilhausen, et al, filed November 7, 1989, and CDMA Network Engineering Handbook by Qualcomm, Inc., [ ]each of which is also incorporated herein by reference.

The paragraph beginning on page 16, line 6 has been replaced with the following paragraph:

As mentioned [in (1.7) and]in the discussion of classification FOMs above, the present invention can substantially automatically retrain and/or recalibrate itself to compensate for variations in wireless signal characteristics (e.g., multipath) due to environmental and/or topographic changes to a geographic area serviced by the present invention. For example, in one embodiment, the present invention optionally includes low cost, low power base stations, denoted location base stations (LBS) above, providing, for example, CDMA pilot channels to a very limited area about each such LBS. The location base stations may provide limited voice traffic capabilities, but each is capable of gathering sufficient wireless signal characteristics from an MS within the location base station's range to facilitate locating the MS. Thus, by positioning the location base stations at known locations in a geographic region such as, for instance, on street lamp poles and road signs, additional MS location accuracy can be obtained. That is, due to the low power signal output by such location base stations, for there to be signaling control communication (e.g., pilot signaling and other control signals) between a location base station and a target MS, the MS must be relatively near the location base station. Additionally, for each location base station not in communication with the target MS, it is likely that the MS is not near to this location base station. Thus, by utilizing information received from both location base stations in communication with the target MS and those that are not in communication with the target MS, the present invention can substantially narrow the possible geographic areas within which the target MS is likely to be. Further, by providing each location base station (LBS) with a co-located stationary wireless transceiver (denoted a built-in MS above) having similar functionality to an MS, the following advantages are provided:

The paragraph beginning on page 17, line 12 has been replaced with the following paragraph:

It is also an aspect of the present invention to automatically (re)calibrate as in (6.3) above with signal characteristics from other known or verified locations. In one embodiment of the present invention, portable location verifying electronics are provided so that when such electronics are sufficiently near a located target MS, the electronics: (i)[(I)] detect the proximity of the target MS; (ii) determine a highly reliable measurement of the location of the target MS; (iii) provide this measurement to other location determining components of the present invention so that the location measurement can be associated and archived with related signal characteristic data received from the target MS at the location where the

location measurement is performed. Thus, the use of such portable location verifying electronics allows the present invention to capture and utilize signal characteristic data from verified, substantially random locations for location system calibration as in (6.3) above. Moreover, it is important to note that such location verifying electronics can verify locations automatically wherein it is unnecessary for manual activation of a location verifying process.

The paragraph beginning on page 18, line 6 has been replaced with the following paragraph:

Furthermore, a mobile location base station includes modules for integrating or reconciling distinct mobile location base station location estimates that, for example, can be obtained using the components and devices of (7.1) through (7.4) above. That is, location estimates for the mobile location base station may be obtained from: GPS satellite data, mobile location base station data provided by the location processing center, [dead reckoning] <u>deadreckoning</u> data obtained from the mobile location base station vehicle [dead reckoning] <u>deadreckoning</u> devices, and location data manually input by an operator of the mobile location base station.

The paragraph beginning on page 18, line 11 has been replaced with the following paragraph:

[ ]The location estimating system of the present invention offers many advantages over existing location systems. The system of the present invention, for example, is readily adaptable to existing wireless communication systems and can accurately locate people and/or objects in a cost effective manner. In particular, the present invention requires few, if any, modifications to commercial wireless communication systems for implementation. Thus, existing personal communication system infrastructure base stations and other components of, for example, commercial CDMA infrastructures are readily adapted to the present invention. The present invention can be used to locate people and/or objects that are not in the line-of-sight of a wireless receiver or transmitter, can reduce the detrimental effects of multipath on the accuracy of the location estimate, can potentially locate people and/or objects located indoors as well as outdoors, and uses a number of wireless stationary transceivers for location. The present invention employs a number of distinctly different location computational models for location which provides a greater degree of accuracy, robustness and versatility than is possible with existing systems. For instance, the location models provided include not only the radius-radius/TOA and TDOA techniques but also adaptive artificial neural net techniques. Further, the present invention is able to adapt to the topography of an area in which location service is desired. The present invention is also able to adapt to environmental changes substantially as frequently as desired. Thus, the present invention

is able to take into account changes in the location topography over time without extensive manual data manipulation. Moreover, the present invention can be utilized with varying amounts of signal measurement inputs. Thus, if a location estimate is desired in a very short time interval (e.g., less than approximately one to two seconds), then the present location estimating system can be used with only as much signal measurement data as is possible to acquire during an initial portion of this time interval. Subsequently, after a greater amount of signal measurement data has been acquired, additional more accurate location estimates may be obtained. Note that this capability can be useful in the context of 911 emergency response in that a first quick [course]coarse wireless mobile station location estimate can be used to route a 911 call from the mobile station to a 911 emergency response center that has responsibility for the area containing the mobile station and the 911 caller. Subsequently, once the 911 call has been routed according to this first quick location estimate, by continuing to receive additional wireless signal measurements, more reliable and accurate location estimates of the mobile station can be obtained.

The paragraph beginning on page 19, line 5 through page 19, line 19 has been replaced with the following paragraph:

At a more general level, it is an aspect of the present invention to demonstrate the utilization of various novel computational paradigms such as:

(8.1) providing a multiple hypothesis computational architecture (as illustrated best in [Fig. 8] Figs. 8) wherein the hypotheses are:

(8.1.1) generated by modular independent hypothesizing computational models;

(8.1.2) the models are embedded in the computational architecture in a manner wherein the architecture allows for substantial amounts of application specific processing common or generic to a plurality of the models to be straightforwardly incorporated into the computational architecture;

(8.1.3) the computational architecture enhances the hypotheses generated by the models both according to past performance of the models and according to application specific constraints and heuristics without requiring feedback loops for adjusting the models;

(8.1.4) the models are relatively easily integrated into, modified and extracted from the computational architecture;

(8.2) providing a computational paradigm for enhancing an initial estimated solution to a problem by using this initial estimated solution as, effectively, a query or index into an historical data base of

previous solution estimates and corresponding actual solutions for deriving an enhanced solution estimate based on past performance of the module that generated the initial estimated solution.

The paragraph beginning on page 20, line 19 has been replaced with the following paragraph:

In other embodiments of the present invention, a fast, [abeit]albeit less accurate location estimate may be initially performed for very time critical location applications where approximate location information may be required. For example, less than 1 second response for a mobile station location embodiment of the present invention may be desired for 911 emergency response location requests. Subsequently, once a relatively [course]coarse location estimate has been provided, a more accurate most likely location estimate can be performed by repeating the location estimation processing a second time with, e.g., additional with measurements of wireless signals transmitted between a mobile station to be located and a network of base stations with which the mobile station is communicating, thus providing a second, more accurate location estimate of the mobile station.

The paragraph beginning on page 21, line 1 has been replaced with the following paragraph:

Note that in some embodiments of the present invention, since there is a lack of sequencing between the FOMs and subsequent processing of location hypotheses, the FOMs can be incorporated into an expert system, if desired. For example, each FOM may be activated from an antecedent of an expert system rule. Thus, the antecedent for such a rule can evaluate to TRUE if the FOM outputs a location hypothesis, and the consequent portion of such a rule may put the output location hypothesis on a list of location hypotheses occurring in a particular time window for subsequent processing by the location center. Alternatively, activation of the FOMs may be in the consequents of such expert system rules. That is, the antecedent of such an expert system rule may determine if the conditions are appropriate for invoking the FOM(s) in the rule's consequent.

The paragraph beginning on page 21, line 8 has been replaced with the following two paragraphs. Note that the only difference here is the commencement of a new paragraph at –Further features and advantages–.

Of course, other software architectures may also to used in implementing the processing of the location center without departing from scope of the present invention. In particular, object-oriented architectures are also within the scope of the present invention. For example, the FOMs may be object methods on an MS location estimator object, wherein the estimator object receives substantially all target MS location signal data output by the signal filtering subsystem. Alternatively, software bus architectures are contemplated by the present invention, as one skilled in the art will understand, wherein the software architecture may be modular and facilitate parallel processing.

Further features and advantages of the present invention are provided by the figures and detailed description accompanying this invention summary.

The paragraph beginning on page 22, line 5 has been replaced with the following paragraph:

Fig. 3 provides a typical example of how the statistical power budget is calculated in design of a Commercial Mobile Radio Service Provider <u>(CMRS)</u> network.

The paragraph beginning on page 22, line 14 has been replaced with the following paragraph:

Fig<u>s</u>. 9<u>A and 9A</u> is a high level data structure diagram describing the fields of a location hypothesis object generated by the first order models 1224 of the location center.

The paragraph beginning on page 23, line 16 has been replaced with the following paragraph:

Figs. 23[a]<u>A</u> through 23[b]<u>C</u> present a high level flowchart of the steps performed by function, "GET_DIFFERENCE_MEASUREMENT," for updating location signatures in the location signature data base 1320; note, this flowchart corresponds to the description of this function in APPENDIX C.

The paragraph beginning on page 28, line 9 has been replaced with the following paragraph:

The MBS 148 acts as a low cost, partially-functional, moving base station, and is, in one embodiment, situated in a vehicle where an operator may engage in MS 140 searching and tracking activities. In providing these activities using CDMA, the MBS 148 provides a forward link pilot channel for a target MS 140, and subsequently receives unique BS pilot strength measurements from the MS 140.

The MBS 148 also includes a mobile station for data communication with the LC 142, via a BS 122. In particular, such data communication includes telemetering the geographic position of the MBS 148 as well as various RF measurements related to signals received from the target MS 140. In some embodiments, the MBS 148 may also utilize multiple-beam fixed antenna array elements and/or a moveable narrow beam antenna[ ], such as a microwave dish 182. The antennas for such embodiments may have a known orientation in order to further deduce a radio location of the target MS 140 with respect to an estimated current location of the MBS 148. As will be described in more detail herein below, the MBS 148 may further contain a global positioning system (GPS), distance sensors, [dead-reckoning]deadreckoning electronics, as well as an on-board computing system and display devices for locating both the MBS 148 [of]itself as well as tracking and locating the target MS 140. The computing and display provides a means for communicating the position of the target MS 140 on a map display to an operator of the MBS 148.

The paragraph beginning on page 29, line 15 has been replaced with the following two paragraphs. Note that the only difference here is the commencement of a new paragraph at –Thus, LBSs 152–.

It should be noted that an LBS 152 will normally deny hand-off requests, since typically the LBS does not require the added complexity of handling voice or traffic bearer channels, although economics and peak traffic load conditions would dictate preference here. GPS timing information, needed by any CDMA base station, is either achieved via a the inclusion of a local GPS receiver or via a telemetry process from a neighboring conventional BS 122, which contains a GPS receiver and timing information. Since energy requirements are minimal in such an LBS 152, (rechargeable) batteries or solar cells may be used to power the LBS. No expensive terrestrial transport link is typically required since two-way communication is provided by the included MS 140 (or an electronic variation thereof).

Thus, LBSs 152 may be placed in numerous locations, such as:

(a) in dense urban canyon areas (e.g., where signal reception may be poor and/or very noisy);
(b) in remote areas (e.g., hiking, camping and skiing areas);
(c) along highways (e.g., for emergency as well as monitoring traffic flow), and their rest stations; or
(d) in general, wherever more location precision is required than is obtainable using other wireless [infrastruction] infrastructure network components.

The paragraph beginning on page 29, line 29 has been replaced with the following paragraph:

A location application programming interface [136 (Fig. 4);]or L-API 14 (see Fig. 30, and including L-API-Loc_APP 135, L-API-MSC 136, and L-API-SCP 137 shown in Fig. 4), is required between the location center 142 (LC) and the mobile switch center (MSC) network element type, in order to send and receive various control, signals and data messages. The L-API 14 should be implemented using a preferably high-capacity physical layer communications interface, such as IEEE standard 802.3 (10 baseT Ethernet), although other physical layer interfaces could be used, such as fiber optic ATM, frame relay, etc. Two forms of API implementation are possible. In the first case the signals control and data messages are realized using the MSC 112 vendor's native operations messages inherent in the product offering, without any special modifications. In the second case the L-API includes a full suite of commands and messaging content specifically optimized for wireless location purposes, which may require some, although minor development on the part of the MSC vendor.

The paragraph beginning on page 30, line 6 has been replaced with the following paragraph:

Referring to Fig. 30, the signal processing subsystem 1220 receives control messages and signal measurements and transmits appropriate control messages to the wireless network via the location applications programming interface referenced earlier, for wireless location purposes. The signal processing subsystem additionally provides various signal [idintification]identification, conditioning and pre-processing functions, including buffering, signal type classification, signal filtering, message control and routing functions to the location estimate modules.

The paragraph beginning on page 30, line 11 has been replaced with the following paragraph:

There can be several combinations of Delay Spread/Signal Strength sets of measurements made available to the signal processing subsystem [20]1220. In some cases the mobile station 140 ([Fig. 1]Fig. 4) may be able to detect up to three or four Pilot Channels representing three to four Base Stations, or as few as one Pilot Channel, depending upon the environment. Similarly, possibly more than one BS 122 can detect a mobile station 140 transmitter signal, as evidenced by the provision of cell diversity or soft hand-off in the CDMA standards, and the fact that multiple CMRS' base station equipment commonly will overlap coverage areas. For each mobile station 140 or BS 122 transmitted signal detected by a

receiver group at a station, multiple delayed signals, or "fingers" may be detected and tracked resulting from multipath radio propagation conditions, from a given transmitter.

The paragraph beginning on page 30, line 23 has been replaced with the following paragraph:

From the mobile receiver's perspective, a number of combinations of measurements could be made available to the Location Center. Due to the disperse and near-random nature of CDMA radio signals and propagation characteristics, traditional TOA/TDOA location methods have failed in the past, because the number of signals received in different locations [area]are different. In a particularly small urban area, of say less than 500 square feet, the number of RF signals and [there]their multipath components may vary by over 100 percent.

The paragraph beginning on page 31, line 19 has been replaced with the following paragraph:

Although Rayleigh fading appears as a generally random noise generator, essentially destroying the correlation value of either $RRSS_{BS}$ or $SRSS_{MS}$ measurements with distance individually, several mathematical operations or signal processing functions can be performed on each measurement to derive a more robust relative signal strength value, overcoming the adverse Rayleigh fading effects. Examples include averaging, taking the strongest value and weighting the strongest value with a greater coefficient than the weaker value, then averaging the results. This signal processing technique takes advantage of the fact that although a Rayleigh fade may often exist in either the forward or reverse path, it is much less probable that a Rayleigh fade also exists in the reverse or forward path, respectively. A shadow fade however, [similiarly]similarly affects the signal strength in both paths.

The paragraph beginning on page 31, line 26 has been replaced with the following paragraph:

At this point a CDMA radio signal [direction-independent "]direction independent of "net relative signal strength measurement" [is]can be derived which [is]can be used to establish a correlation with either distance or shadow fading, or both. Although the ambiguity of either shadow fading or distance cannot be determined, other means can be used in conjunction, such as the fingers of the CDMA delay spread measurement, and any other TOA/TDOA calculations from other geographical points. In the case of a mobile station with a certain amount of shadow fading between its BS 122 (Fig. 2), the first finger of

a CDMA delay spread signal is most likely to be a relatively shorter duration than the case where the mobile station 140 and BS 122 are separated by a greater distance, since shadow fading does not materially affect the arrival time delay of the radio signal.

The paragraph beginning on page 31, line 33 has been replaced with the following paragraph:

By performing a small modification in the control electronics of the CDMA base station and mobile station receiver circuitry, it is possible to provide the signal processing subsystem [20]1220 (reference Fig. 30) within the [L]location [scenter]center 142 (Fig. 1) with data that exceed the one-to-one CDMA delay-spread fingers to data receiver correspondence. Such additional information, in the form of additional CDMA fingers (additional multipath) and all associated detectable pilot channels, provides new information which is used to enhance [to]the accuracy of the [L]location [C]center's location estimators [estimate location estimate modules].

The paragraph beginning on page 32, line 4 has been replaced with the following paragraph:

This enhanced capability is provided via a control message, sent from the [Location]location center 142 to the mobile switch center 12, and then to the base station(s) in communication with, or in close proximity with, mobile stations 140 to be located. Two types of location measurement request control messages are needed: one to instruct a target mobile station 140 (i.e., the mobile station to be located) to telemeter its BS pilot channel measurements back to the primary BS 122 and from there to the mobile switch center 112 and then to the location system 42. The second control message is sent from the location system 42 to the mobile switch center 112, then to first the primary BS, instructing the primary BS' searcher receiver to output (i.e., return to the initiating request message source) the detected target mobile station 140 transmitter CDMA pilot channel offset signal and their corresponding delay spread finger (peak) values and related relative signal strengths.

The paragraph beginning on page 32, line 24 has been replaced with the following paragraph:

Fig. 30 illustrates the components of the Signal Processing Subsystem 1220 (also shown in Figs. 5, 6 and 8). The main components consist of the input queue(s) 7, signal classifier/filter 9, digital signaling processor 17, imaging filters 19, output queue(s) 21, router/distributor 23, (also denoted as the

"Data Capture And Gateway" in Fig. 8(2)), a signal processor database 26 and a signal processing controller 15.

The paragraph beginning on page 33, line 3 has been replaced with the following paragraph:

The signal processing subsystem 1220 supports a variety of wireless network signaling measurement capabilities by detecting the capabilities of the mobile and base station through messaging structures provided [bt]by the location application programming interface (L-API 14, Fig. 30). Detection is accomplished in the signal classifier 9 (Fig. 30) by referencing a mobile station database table within the signal processor database 26, which provides, given a mobile station identification number, mobile station revision code, other mobile station [charactersitics]characteristics. [Similiarly] Similarly, a mobile switch center table 31 provides MSC characteristics and identifications to the signal classifier/filter 9. The signal classifier/filter adds additional message header information that further classifies the measurement data which allows the digital signal processor and image filter components to select the proper internal processing subcomponents to perform operations on the signal measurement data, for use by the location estimate modules.

The paragraph beginning on page 33, line 11 and ending on page 33, line 18 has been replaced with the following paragraph.

Regarding service control point messages (of L-API-SCP interface 137, Fig. 4) autonomously received from the input queue 7 (Figs. 30 and 31), the signal classifier/filter 9 [detemines]determines via a signal processing database 26 query [that the]whether such a message is to be associated with a home base station module. Thus appropriate header information is added to the message, thus enabling the message to pass through the digital signal processor 17 unaffected to the output [queu]queue 21, and then to the router/distributor 23. The router/distributor 23 then routes the message to the HBS first order model. Those skilled in the art will understand that associating location requests from Home Base Station configurations require substantially less data: the mobile identification number and the associated wireline telephone number transmission from the home location register are on the order of less than 32 bytes. Consequentially the home base station message type could be routed without any digital signal processing.

The paragraph beginning on page 33, line 19 has been replaced with the following paragraph:

______Output queue(s) 21 (Fig. 30) are required for similar reasons as input queues 7: relatively large amounts of data must be held in a specific format for further location processing by the location estimate modules 1224.

The paragraph beginning on page 33, line 21 through page 33, line 23 has been replaced with the following paragraph:

The router and distributor component 23 (Fig. 30) is responsible [to]for directing specific signal measurement data types and structures to their appropriate modules. For example, the HBS FOM has no use for digital filtering structures, whereas the TDOA module would not be able to process an HBS response message.

The paragraph beginning on page 33, line 24 has been replaced with the following paragraph:

_______The controller 15 (Fig. 30) is responsible for staging the movement of data among the signal processing subsystem [20]1220 components input queue 7, digital signal processor 17, router/distributor 23 and the output queue 21, and to initiate signal [measurments]measurements within the wireless network, in response from an internet [168]468 location request message in Fig. [1]5, via the location application programming interface.

The paragraph beginning on page 33, line 27 has been replaced with the following paragraph:

In addition the controller 15 receives autonomous messages from the MSC[ ], via the location applications programming interface [(Fig. 1)]or L-API 14 (Fig. 30) and the input queue 7, whenever a 9-1-1 wireless call is originated. The mobile switch center provides this autonomous notification to the location system as follows: [By specifiying]by specifying the appropriate mobile switch center operations and maintenance commands to surveil calls based on certain digits dialed such as 9-1-1, the location applications programming interface 14, in communications with the MSCs, receives an autonomous notification whenever a mobile station user dials 9-1-1. Specifically, a bi-directional authorized communications port is configured, usually at the operations and maintenance subsystem of the MSCs, or with their associated network element manager system(s), with a data circuit, such as a DS-

1, with the location applications programming interface [in Fig. 1]14. Next, the "call trace" capability of the mobile switch center is activated for the respective communications port. The exact implementation of the vendor-specific man-machine or Open Systems Interface (OSI) command[s](s) and their associated data structures generally vary among MSC vendors.[, however] However, the trace function is generally available in various forms, and is required in order to comply with Federal Bureau of Investigation authorities for wire tap purposes. After the appropriate surveillance commands are established on the MSC, such 9-1-1 call notifications messages containing the mobile station identification number (MIN) and, in U.S. FCC phase 1 E9-1-1 implementations, a pseudo-automatic number [identication]identification (a.k.a. pANI) which provides an association with the primary base station in which the 9-1-1 caller is in [communicaiton]communication. In cases where the pANI is known from the onset, the signal processing subsystem 1220 avoids querying the MSC in question to determine the primary base station identification associated with the 9-1-1 mobile station caller.

The paragraph beginning on page 34, line 10 has been replaced with the following paragraph:

After the signal processing controller 15 receives the first message type, the autonomous notification message from the mobile switch center 112 to the location system 142[42], containing the mobile identification number and optionally the primary base station identification, the controller 15 queries the base station table 13 (Fig. 30) in the signal processor database 26 to determine the status and availability of any neighboring base stations, including those base stations of other CMRS in the area. The definition of neighboring base stations include not only those within a provisionable "hop" based on the cell design reuse factor, but also includes, in the case of CDMA, results from remaining set information autonomously queried to mobile stations, with results stored in the base station table. Remaining set information indicates that mobile stations can detect other base station (sector) pilot channels which may exceed the "hop" distance, yet are nevertheless candidate base stations (or sectors) for wireless location purposes. Although cellular and digital cell design may vary, "hop" distance is usually one or two cell coverage areas away from the primary base station's cell coverage area.

The paragraph beginning on page 34, line 20 has been replaced with the following paragraph:

Having determined a likely set of base stations which may both detect the mobile station's transmitter signal, as well as to determine the set of likely pilot channels (i.e., base stations and their associated physical antenna sectors) detectable by the mobile station in the area surrounding the primary

base station (sector), the controller 15 initiates messages to both the mobile station and appropriate base stations (sectors) to perform signal measurements and to return the results of such measurements to the signal processing system regarding the mobile station to be located. This step may be accomplished via several interface means. In a first case the controller 15 utilizes, for a given MSC, predetermined storage information in the MSC table 31 to determine which type of commands, such as man-machine or OSI commands are needed to request such signal [measrurements]measurements for a given MSC. The controller generates the mobile and base station signal measurement commands appropriate for the MSC and passes the commands via the input queue 7 and the locations application programming interface 14 in Fig. 30[in Fig.1], to the appropriate MSC, using the authorized communications port mentioned earlier. In a second case, the controller 15 communicates directly with base stations within having to interface directly with the MSC for signal measurement extraction.

The paragraph beginning on page 34, line 31 has been replaced with the following paragraph:

Upon receipt of the signal measurements, the signal classifier 9 in Fig. 30 examines location application programming interface-provided message header information from the source of the location measurement (for example, from a fixed BS 122, a mobile station 140, a distributed antenna system 168 in Fig. [1]4 or message location data related to a home base station), provided by the location applications programming interface (L-API 14) via the input queue 7 in Fig. 30 and determines whether or not device filters 17 or image filters 19 are needed, and assesses a relative priority in processing, such as an emergency versus a background location task, in terms of grouping like data associated with a given location request. In the case where multiple signal measurement requests are outstanding for various base stations, some of which may be associated with a different CMRS network, and additional signal classifier function includes sorting and associating the appropriate incoming signal measurements together such that the digital signal processor 17 processes related measurements in order to build ensemble data sets. Such ensembles allow for a variety of functions such as averaging, outlier removal over a time period, and related filtering functions, and further prevent association errors from [occuring]occurring in location estimate processing.

The paragraph beginning on page 35, line 10 has been replaced with the following paragraph:

Another function of the signal classifier/low pass filter component 9 is to filter information that is not useable, or information that could introduce noise or the effect of noise in the location estimate

modules. Consequently low pass matching filters are used to match the in-common signal processing components to the characteristics of the incoming signals. Low pass filters match: Mobile Station, base station, CMRS and MSC characteristics, as [wall]well as to classify Home Base Station messages.

The paragraph beginning on page 35, line 14 has been replaced with the following paragraph:

The signal processing subsystem 1220 contains a base station database table [ ]13 (Fig. 30) which captures the maximum number of CDMA delay spread fingers for a given base station.

The paragraph beginning on page 35, line 21 has been replaced with the following paragraph:

Just as an upgraded base station may detect additional CDMA delay spread signals, newer or modified mobile stations may detect additional pilot channels or CDMA delay spread fingers. Additionally different makes and models of mobile stations may acquire improved receiver sensitivities, suggesting a greater coverage capability. [The] A table [below establishes]may establish the relationships among various mobile station equipment suppliers and certain technical data relevant to this location invention.

The paragraph beginning on page 35, line 25 has been replaced with the following paragraph:

Although not strictly necessary, [The]the MIN can be populated in this table from the PCS Service Provider's Customer Care system during subscriber activation and fulfillment, and could be changed at deactivation, or anytime the end-user changes mobile stations. Alternatively, since the MIN, manufacturer, model number, and software revision level information is available during a telephone call, this information could extracted during the call, and the remaining fields populated dynamically, based on manufacturer's' specifications information previously stored in the signal processing subsystem [20]1220. Default values are used in cases where the MIN is not found, or where certain information must be estimated.

The paragraph beginning on page 35, line 31 has been replaced with the following paragraph:

A low pass mobile station filter, contained within the signal classifier/low pass filter 9 of the signal processing subsystem [20]1220, uses the above table data to perform the following functions: 1) act as a low pass filter to adjust the nominal assumptions related to the maximum number of CDMA

fingers, pilots detectable; and 2) [ ]to determine the transmit power class and the receiver thermal noise floor. Given the detected reverse path signal strength, the required value of $SRSS_{MS,[ ]}$ a corrected indication of the effective path loss in the reverse direction (mobile station to BS), can be calculated based on data contained within the mobile station table 11, stored in the signal processing database 26.

The paragraph beginning on page 36, line 3 has been replaced with the following paragraph:

The effects of the maximum [Number]number of CDMA fingers allowed and the maximum number of pilot channels allowed essentially form a low pass filter effect, wherein the least common denominator of characteristics are used to filter the incoming RF signal measurements such that a one for one matching occurs. The effect of the transmit power class and receiver thermal noise floor values is to normalize the characteristics of the incoming RF signals with respect to those RF signals used.

The paragraph beginning on page 36, line 7 has been replaced with the following paragraph:

The signal classifier/filter [20]9 (Fig. 30) is in communication with both the input queue 7 and the signal processing database 26. In the early stage of a location request the signal processing subsystem [142]1220 shown in, e.g., [in]Figs. [4]5, 30 and 31, will receive the initiating location request from either an autonomous 9-1-1 notification message from a given MSC, or from a location application[(for example, see Fig. 36)], for which mobile station characteristics about the target mobile station 140 (Fig. [1]4) is required. Referring to Fig. 30, a query is made from the signal processing controller 15 to the signal [processning]processing database 26, specifically the mobile station table 11, to determine if the mobile station characteristics associated with the MIN to be located is available in table 11. [if] If the data exists then there is no need for the controller 15 to query the wireless network in order to determine the mobile station characteristics, thus avoiding additional real-time processing which would otherwise be required across the air interface, in order to determine the mobile station MIN characteristics. The resulting mobile station information my be provided either via the signal processing database 26 or alternatively a query may be performed directly from the signal processing subsystem [20]1220 to the MSC in order to determine the mobile station characteristics.

The paragraph beginning on page 36, line 18 has been replaced with the following paragraph. Note that a new Fig. 31 is provided with the label "139" changed to –239–. This is being done since the label "139" is already being used to denote the "location engine."

Referring now to Fig. 31, [a]another location application programming interface, L-API-CCS [139]239 to the appropriate CMRS customer care system provides the mechanism to populate and update the mobile station table 11 within the database 26. The L-API-CCS [139]239 contains its own set of separate input and output queues or similar implementations and security controls to ensure that provisioning data is not sent to the incorrect CMRS, and that a given CMRS cannot access any other CMRS' data. The interface 1155a to the customer care system for CMRS-A 1150a provides an autonomous or periodic notification and response application layer protocol type, consisting of add, delete, change and verify message functions in order to update the mobile station table 11 within the signal processing database 26, via the controller 15. A similar interface [1155b]155b is used to enable provisioning updates to be received from CMRS-B customer care system 1150b.

The paragraph beginning on page 36, line 26 has been replaced with the following paragraph:

Although the L-API-CCS application message set may be any protocol type which supports the autonomous notification message with positive acknowledgment type, the T1M1.5 group within the American National Standards Institute has defined a good starting point in which the L-API-CCS 239 could be implemented, using the robust OSI TMN X-interface at the service management layer. The object model defined in Standards proposal number T1M1.5/96-22R9, Operations Administration, Maintenance, and Provisioning (OAM&P) - Model for Interface Across Jurisdictional Boundaries to Support Electronic Access Service Ordering: Inquiry Function, can be extended to support the L-API-CCS information elements as required and further discussed below. Other choices in which the L-API-CCS application message set may be implemented include ASCII, binary, or any encrypted message set encoding using the Internet protocols, such as TCP/IP, simple network management protocol, http, https, and email protocols.

The paragraph beginning on page 37, line 12 has been replaced with the following paragraph:

In the general case where a mobile station is located in an environment with varied clutter. patterns, such as terrain undulations, unique man-made structure geometries (thus creating varied multipath signal behaviors), such as a city or suburb, although the first CDMA delay spread finger may be the same value for a fixed distance between the mobile station and BS antennas, as the mobile station moves across such an [arc]area, different finger-data are measured. In the right image for the defined BS

antenna sector, location classes, or squares numbered one through seven, are shown across a particular range of line of position (LOP).

The paragraph beginning on page 37, line 17 has been replaced with the following paragraph:

A traditional TOA/TDOA ranging method between a given BS and mobile station only provides a range along [the]an arc, thus introducing ambiguity error. However a unique three dimensional image can be used in this method to specifically identify, with recurring probability, a particular unique location class along the same Line Of Position, as long as the multipath is unique by position but generally repeatable, thus establishing a method of not only ranging, but also of complete latitude, longitude location estimation in a Cartesian space. In other words, the unique shape of the "mountain image" enables a correspondence to a given unique location class along a line of position, thereby eliminating traditional ambiguity error.

The paragraph beginning on page 38, line 17 has been replaced with the following paragraph:

The DSP 17 may provide data [emsemble]ensemble results, such as extracting the shortest time delay with a detectable relative signal strength, to the router/distributor 23, or alternatively results may be processed via one or more image filters 19, with subsequent transmission to the router/distributor 23. The router/distributor 23 examines the processed message data from the DSP 17 and stores routing and distribution information in the message header. The router/distributor 23 then forwards the data messages to the output queue 21, for subsequent queuing then transmission to the appropriate location estimator FOMs.

The paragraph beginning on page 38, line 24 and ending on page 39, line 14 has been replaced with the following paragraph:

At a very high level the location center [ ]142 computes location estimates for a wireless Mobile Station 140 (denoted the "target MS" or "MS") by performing the following steps:

(23.1) receiving signal transmission characteristics of communications communicated between the target MS 140 and one or more wireless infrastructure base stations 122;

(23.2) filtering the received signal transmission characteristics (by a signal processing subsystem 1220 illustrated in Fig. 5) as needed so that target MS location data can be generated that is uniform and

consistent with location data generated from other target MSs 140. In particular, such uniformity and consistency is both in terms of data structures and interpretation of signal characteristic values provided by the MS location data;

(23.3) inputting the generated target MS location data to one or more MS location estimating models (denoted First order models or FOMs, and labeled collectively as 1224 in Fig. 5), so that each such model may use the input target MS location data for generating a "location hypothesis" providing an estimate of the location of the target MS 140;

(23.4) providing the generated location hypotheses to an hypothesis evaluation module (denoted the hypothesis evaluator 1228 in Fig. 5):

(a) for adjusting at least one of the target MS location estimates of the generated location hypotheses and related confidence values indicating the confidence given to each location estimate, wherein such adjusting uses archival information related to the accuracy of previously generated location hypotheses,

(b) for evaluating the location hypotheses according to various heuristics related to, for example, the radio coverage area 120 terrain, the laws of physics, characteristics of likely movement of the target MS 140; and

(c) for determining a most likely location area for the target MS 140, wherein the measurement of confidence associated with each input MS location area estimate is used for determining a "most likely location area"; and

(23.5) outputting a most likely target MS location estimate to one or more applications [1232]146 (Fig. [2.0]5) requesting an estimate of the location of the target MS 140.

The paragraph beginning on page 42, line 1 has been replaced with the following paragraph:

Additionally, in utilizing location hypotheses in, for example, the location evaluator 1228 as in (23.4) above, it is important to keep in mind that each location hypothesis confidence value is a relative measurement. That is, for confidences, cf_1 and cf_2, if $cf_1 <= cf_2$, then for a location hypotheses H_1 and H_2 having cf_1 and cf_2, respectively, the target MS 140 is expected to more likely reside in a target MS estimate of H_2 than a target MS estimate of H_1. Moreover, if an area, A, is such that it is included in a plurality of location hypothesis target MS estimates, then a confidence score, CS_A, can be assigned to A, wherein the confidence score for such an area is a function of the confidences (both positive and negative) for all the location hypotheses whose (most pertinent) target MS location estimates contain A. That is, in order to determine a most likely target MS location area estimate for outputting from the location center

142, a confidence score is determined for areas within the location center service area. More particularly, if a function, "f", is a function of the confidence(s) of location hypotheses, and f is a monotonic function in its parameters and $f(cf_1, cf_2, cf_3, \ldots, cf_N) = CS_A$ for confidences cf_i of location hypotheses H_i, $i=1,2,\ldots,N$, with CS_A contained in the area estimate for H_i, then "f" is denoted a confidence score function. [ ]Accordingly, there are many embodiments for a confidence score function f that may be utilized in computing confidence scores with the present invention; e.g.,

(a) $f(cf_1, cf_2, \ldots, cf_N) = [S]\underline{\Sigma}\, cf_i = CS_A$;

(b) $f(cf_1, cf_2, \ldots, cf_N) = [S]\underline{\Sigma}\, cf_i^n = CS_A, n = 1, 3, 5, \ldots$;

(c) $f(cf_1, cf_2, \ldots, cf_N) = [S]\underline{\Sigma}\, (K_i * cf_i) = CS_A$, wherein K_i, $i = 1, 2, \ldots$ are positive system (tunable) constants (possibly dependent on environmental characteristics such as topography, time, date, traffic, weather, and/or the type of base station(s) 122 from which location signatures with the target MS 140 are being generated, etc.).

The paragraph beginning on page 43, line 27 and ending on page 44, line 23 has been replaced with the following paragraph:

In one embodiment of a method and system for determining such (transmission) area type approximations, a partition (denoted hereinafter as P_0) is imposed upon the radio coverage area 120 for partitioning for radio coverage area into subareas, wherein each subarea is an estimate of an area having included MS 140 locations that are likely to have is at least a minimal amount of similarity in their wireless signaling characteristics. To obtain the partition P_0 of the radio coverage area 120, the following steps are performed:

(23.8.4.1) Partition the radio coverage area 120 into subareas, wherein in each subarea is: (a) connected, (b) variations in the lengths of chords sectioning the subarea through the centroid of the subarea are below a predetermined threshold, (c) the subarea has an area below a predetermined value, and (d) for most locations (e.g., within a first or second <u>standard</u> deviation) within the subarea whose wireless signaling characteristics have been verified, it is likely (e.g., within a first or second <u>standard</u> deviation) that an MS 140 at one of these locations will detect (forward transmission path) and/or will be detected (reverse transmission path) by a same collection of base stations 122. For example, in a CDMA context, a first such collection may be (for the forward transmission

path) the active set of base stations 122, or, the union of the active and candidate sets, or, the union of the active, candidate and/or remaining sets of base stations 122 detected by "most" MSs 140 in the subarea. Additionally (or alternatively), a second such collection may be the base stations 122 that are expected to detect MSs 140 at locations within the subarea. Of course, the union or intersection of the first and second collections is also within the scope of the present invention for partitioning the radio coverage area 120 according to (d) above. It is worth noting that it is believed that base station 122 power levels will be substantially constant. However, even if this is not the case, one or more collections for (d) above may be determined empirically and/or by computationally simulating the power output of each base station 122 at a predetermined level. Moreover, it is also worth mentioning that this step is relatively straightforward to implement using the data stored in the location signature data base 1320 (i.e., the verified location signature clusters discussed in detail hereinbelow). Denote the resulting partition here as P_1.

(23.8.4.2) Partition the radio coverage area 120 into subareas, wherein each subarea appears to have substantially homogeneous terrain characteristics. Note, this may be performed periodically substantially automatically by scanning radio coverage area images obtained from aerial or satellite imaging. For example, EarthWatch Inc. of Longmont, CO can provide geographic with 3 meter resolution from satellite imaging data. Denote the resulting partition here as P_2.

(23.8.4.3) Overlay both of the above partitions of the radio coverage area 120 to obtain new subareas that are intersections of the subareas from each of the above partitions. This new partition is P_0 (i.e., $P_0 = P_1$ intersect P_2), and the subareas of it are denoted as "P_0 subareas".

The paragraph beginning on page 47, line 4 and ending on page 47, line 22 has been replaced with the following paragraph:

There are four fundamental entity types (or object classes in an object oriented programming paradigm) utilized in the location signature data base 1320. Briefly, these data entities are described in the items (24.1) through (24.4) that follow:

(24.1) (verified) location signatures: Each such (verified) location signature describes the wireless signal characteristic measurements between a given base station (e.g., BS 122 or LBS 152) and an MS 140 at a (verified or known) location associated with the (verified) location signature. That is, a verified location signature corresponds to a location whose coordinates such as latitude-longitude coordinates are known, while simply a location signature may have a known or unknown location corresponding with it. Note that the term (verified) location signature is also denoted by the abbreviation, "(verified) loc sig" hereinbelow;

(24.2) (verified) location signature clusters: Each such (verified) location signature cluster includes a collection of (verified) location signatures corresponding to all the location signatures between a target MS 140 at a (possibly verified) presumed substantially stationary location and each BS (e.g., 122 or 152) from which the target MS 140 can detect the BS's pilot channel [gardless]<u>regardless</u> of the classification of the BS in the target MS (i.e., for CDMA, regardless of whether a BS is in the MS's active, candidate or remaining base station sets, as one skilled in the art will understand). Note that for simplicity here, it is presumed that each location signature cluster has a single fixed primary base station to which the target MS 140 synchronizes or obtains its timing;

(24.3) "composite location objects (or entities)": Each such entity is a more general entity than the verified location signature cluster. An object of this type is a collection of (verified) location signatures that are associated with the same MS 140 at substantially the same location at the same time and each such loc sig is associated with a different base station. However, [ ]there is no requirement that a loc sig from each BS 122 for which the MS 140 can detect the BS's pilot channel is included in the "composite location object (or entity)"; and

(24.4) MS location estimation data that includes MS location estimates output by one or more MS location estimating first order models 1224, such MS location estimate data is described in detail hereinbelow.

The paragraph beginning on page 47, line 30 has been replaced with the following paragraph:

In particular, for each (verified) loc sig includes the following:

(25.1) MS_type: the make and model of the target MS 140 associated with a location signature instantiation; note that the type of MS 140 can also be derived from this entry; e.g., whether MS 140 is a handset MS, car-set MS, or an MS for location only. Note as an aside, for at least CDMA, the type of MS 140 provides information as to the number of fingers that may be measured by the MS[.], as one skilled in the will appreciate.

The paragraph beginning on page 48, line 24 has been replaced with the following paragraph:

(25.7) signal topography characteristics: In one embodiment, the signal topography characteristics retained can be represented as characteristics of at least a two-dimensional generated surface. That is, such a surface is generated by the signal processing subsystem 1220 from signal characteristics accumulated over (a relatively short) time interval. For example, in the two-dimensional surface case, the dimensions for the generated surface may be, for example, signal strength and time delay. That is, the accumulations over a brief time interval of signal characteristic measurements between the BS 122 and the MS 140 (associated with the loc sig) may be classified according to the two signal characteristic dimensions (e.g., signal strength and corresponding time delay). That is, by sampling the signal characteristics and classifying the samples according to a mesh of discrete cells or bins, wherein each cell [correspondi]corresponds to a different range of signal strengths and time delays a tally of the number of samples falling in the range of each cell can be maintained. Accordingly, for each cell, its corresponding tally may be interpreted as height of the cell, so that when the heights of all cells are considered, an undulating or mountainous surface is provided. In particular, for a cell mesh of appropriate fineness, the "mountainous surface", is believed to, under most circumstances, provide a contour that is substantially unique to the location of the target MS 140. Note that in one embodiment, the signal samples are typically obtained throughout a predetermined signal sampling time interval of 2-5 seconds [ ]as is discussed elsewhere in this specification. In particular, the signal topography characteristics retained for a loc sig include certain topographical characteristics of such a generated mountainous surface. For example, each loc sig may include: for each local maximum (of the loc sig surface) above a predetermined noise ceiling threshold, the (signal strength, time delay) coordinates of the cell of the local maximum and the corresponding height of the local maximum. Additionally, certain gradients may also be included for characterizing the "steepness" of the surface mountains. Moreover, note that in some embodiments, a frequency may also be associated with each local maximum. Thus, the data retained for each selected local maximum can include a quadruple of signal strength, time delay, height and frequency. Further note that the data types here may [ ]vary. However, for simplicity, in parts of the description of loc sig processing related to the signal characteristics here, it is assumed that the signal characteristic topography data structure here is a vector;

The paragraph beginning on page 49, line 19 has been replaced with the following paragraph:

(25.13) repeatable: TRUE iff the loc sig is "repeatable" (as described hereinafter), FALSE otherwise. Note that each verified loc sig is designated as either "repeatable" or "random". A loc sig is repeatable if the (verified/known) location associated with the loc sig is such that signal characteristic measurements between the associated BS 122 and this MS can be either replaced at periodic time intervals, or updated substantially on demand by most recent signal characteristic measurements between the associated base station and the associated MS 140 (or a comparable MS) at the verified/known location. Repeatable loc sigs may be, for example, provided by stationary or fixed location MSs 140 (e.g., fixed location transceivers) distributed within certain areas of a geographical region serviced by the location center 142 for providing MS location estimates. That is, it is an aspect of the present invention that each such stationary MS 140 can be contacted by the location center 142 (via the base stations of the wireless infrastructure) at substantially any time for providing a new collection (i.e., cluster) of wireless signal characteristics to be associated with the verified location for the transceiver. Alternatively, repeatable loc sigs may be obtained by, for example, obtaining location signal measurements manually from workers who regularly traverse a predetermined route through some portion of the radio coverage area; i.e., postal workers[(as will be described in more detail hereinbelow)].

Please replace the paragraph beginning on page 50, line 17 with the following paragraph:

(26.1) A "normalization" method for normalizing loc sig data according to the associated MS 140 and/or BS 122 signal processing and generating characteristics. That is, the signal processing subsystem 1220, one embodiment being described in the PCT patent application <u>PCT/US97/15933</u>, titled, "Wireless Location Using A Plurality of Commercial Network Infrastructures," by F. W. LeBlanc and the present inventors, <u>filed September 8, 1997 (which has a U.S. national filing that is now U.S. Patent No. 6,236,365, filed July 8, 1999, note, both PCT/US97/15933 and U.S. Patent No. 6,236,365 are incorporated fully by reference herein)</u> provides (methods for loc sig objects) for "normalizing" each loc sig so that variations in signal characteristics resulting from variations in (for example) MS signal processing and generating characteristics of different types of MS's may be reduced. In particular, since wireless network designers are typically designing networks for effective use of hand set MS's 140 having a substantially common minimum set of performance characteristics, the normalization methods provided here transform the loc sig data so that it appears as though

the loc sig was provided by a common hand set MS 140. However, other methods may also be provided to "normalize" a loc sig so that it may be compared with loc sigs obtained from other types of MS's as well. Note that such normalization techniques include, for example, interpolating and extrapolating according to power levels so that loc sigs may be normalized to the same power level for, e.g., comparison purposes.

Normalization for the BS 122 associated with a loc sig is similar to the normalization for MS signal processing and generating characteristics. Just as with the MS normalization, the signal processing subsystem 1220 provides a loc sig method for "normalizing" loc sigs according to base station signal processing and generating characteristics.

The paragraph beginning on page 52, line 10 has been replaced with the following paragraph:

A first functional group of location engine 139 modules is for performing signal processing and filtering of MS location signal data received from a conventional wireless (e.g., CDMA) infrastructure, as discussed in the steps (23.1) and (23.2) above. This group is denoted the signal processing subsystem 1220 herein. One embodiment of such a subsystem is described in the PCT patent application titled, "Wireless Location Using A Plurality of Commercial Network Infrastructures," by F. W. LeBlanc and the present inventor<u>s.</u>[(s). .]

The paragraph beginning on page 52, line 15 has been replaced with the following paragraph:

A second functional group of location engine 139 modules is for generating various target MS 140 location initial estimates, as described in step (23.3). Accordingly, the modules here use input provided by the signal processing subsystem 1220. This second functional group includes one or more signal analysis modules or models, each hereinafter denoted as a first order model 1224 (FOM), for generating location hypotheses for a target MS 140 to be located. Note that it is intended that each such FOM 1224 use a different technique for determining a location area estimate for the target MS 140. A brief description of some types of first order models is provided immediately below. Note that [Fig.]<u>Figs.</u> 8 illustrates another, more [detail]<u>detailed</u> view of the location system for the present invention. In particular, this figure illustrates some of the FOMs 1224 contemplated by the present invention, and additionally illustrates the primary communications with other modules of the location system for the present invention. However, it is important to note that the present invention is not limited to the FOMs 1224 shown and discussed herein. That is, it is a primary aspect of the present invention to easily incorporate FOMs using other signal processing and/or computational location estimating techniques than those presented herein. Further, note

that each FOM type may have a plurality of its models incorporated into an embodiment of the present invention.

The following paragraph as been inserted immediately before the paragraph beginning on page 53, line 10:

In one embodiment, such a distance model may perform the following steps:

(a) Determines a minimum distance between the target MS and each BS using TOA, TDOA, signal strength on both forward and reverse paths;

(b) Generates an estimated error;

(c) Outputs a location hypothesis for estimating a location of a MS: each such hypothesis having: (i) one or more (nested) location area estimates for the MS, each location estimate having a confidence value (e.g., provided using the estimated error) indicating a perceived accuracy, and (ii) a reason for both the location estimate (e.g., substantial multipath, etc) and the confidence.

The paragraph beginning on page 53, line 10 has been replaced with the following paragraph:

Another type of FOM 1224 is a statistically based first order model 1224, wherein a statistical technique, such as regression techniques (e.g., least squares, partial least squares, principle decomposition), or e.g., Bollenger Bands (e.g., for computing minimum and maximum base station offsets). In general, models of this type output location hypotheses that are determined by performing one or more statistical techniques or comparisons between the verified location signatures in location signature data base 1320, and the wireless signal measurements from a target MS. Models of this type are also referred to hereinafter as [ ]a "stochastic signal (first order) model" or a "stochastic FOM" or a "statistical model."

The following paragraph has been inserted immediately before the paragraph beginning on page 53, line 16:

In one embodiment, such a stochastic signal model may output location hypotheses determined by one or more statistical comparisons with loc sigs in the Location Signature database 1320 (e.g., comparing MS location signals with verified signal characteristics for predetermined geographical areas).

The following paragraph has been inserted immediately before the paragraph beginning on page 53, line 24:

In one embodiment, an adaptive learning model such as a model based on an artificial neural network may determine an MS 140 location estimate using base station IDs, data on signal-to-noise, other signal data (e.g., a number of signal characteristics including, e.g., all CDMA fingers). Moreover, the output from such a model may include: a latitude and longitude for a center of a circle having radius R (R may be an input to such an artificial neural network), and is in the output format of the distance model(s).

The paragraph beginning on page 53, line 24 has been replaced with the following paragraph:

Yet another type of FOM 1224 can be based on a collection of dispersed low power, low cost fixed location wireless transceivers (also denoted "location base stations 152" hereinabove) that are provided for detecting a target MS 140 in areas where, e.g., there is insufficient base station 122 infrastructure coverage for providing a desired level of MS 140 location accuracy. For example, it may uneconomical to provide high traffic wireless voice coverage of a typical wireless base station 122 in a nature preserve or at a fair ground that is only populated a few days out of the year. However, if such low cost location base stations 152 can be directed to activate and deactivate via the direction of a FOM 1224 of the present type, then these location base stations can be used to both [location]locate a target MS 140 and also provide indications of where the target MS is not. For example, if there are location base stations 152 populating an area where the target MS 140 is presumed to be, then by activating these location base stations 152, evidence may be obtained as to whether or not the target MS is actually in the area; e.g., if the target MS 140 is detected by a location base station 152, then a corresponding location hypothesis having a location estimate corresponding to the coverage area of the location base station may have a very high confidence value. Alternatively, if the target MS 140 is not detected by a location base station 152, then a corresponding location hypothesis having a location estimate corresponding to the coverage area of the location base station may have a very low confidence value. Models of this type are referred to hereinafter as "location base station models."

The following paragraph has been inserted immediately before the paragraph beginning on page 54, line 3:

In one embodiment, such a location base station model may perform the following steps:

(a) If an input is received then the target MS 140 is detected by a location base station 152 (i.e., a LBS being a unit having a reduced power BS and a MS).

(b) If an input is obtained, then the output is a hypothesis data structure having a small area of the highest confidence.
(c) If no input is received from a LBS then a hypothesis having an area with highest negative confidence is output.

The paragraph beginning on page 54, line 3 has been replaced with the following paragraph:

Yet another type of FOM 1224 can be based on input from a mobile base station 148, wherein location hypotheses may be generated from target MS 140 location data received from the mobile base station 148. In one embodiment, such a mobile base station model may provide output similar to the distance FOM 1224 described hereinabove.

The paragraph beginning on page 54, line 8 and ending on page 54, line 23 has been replaced with the following paragraphs. Note the commencement of two new paragraphs inserted at – Additionally, FOMS 1224—, and at –Moreover, other FOMs—.

Note that the FOM types mentioned here as well as other FOM types are discussed in detail hereinbelow. Moreover, it is [ ]important to keep in mind that a novel aspect of the present invention is the simultaneous use or activation of a potentially large number of such first order models 1224, wherein such FOMs are not limited to those described herein. Thus, the present invention provides a framework for incorporating MS location estimators to be subsequently provided as new FOMs in a straightforward manner. For example, a FOM 1224 based on wireless signal time delay measurements from a distributed antenna system 168 for wireless communication may be incorporated into the present invention for locating a target MS 140 in an enclosed area serviced by the distributed antenna system (such a FOM is more fully described in the U.S. Patent 6,236,365 filed July 8, 1999 which is incorporated fully by reference herein). Accordingly, by using such a distributed antenna FOM 1224 (Fig. 8(1)), the present invention may determine the floor of a multi-story building from which a target MS is transmitting. Thus, MSs 140 can be located in three dimensions using such a distributed antenna FOM 1224.

In one embodiment, such a distributed antenna model may perform the following steps:

(a) Receives input only from a distributed antenna system.
(b) If an input is received, then the output includes a lat-long and height of highest confidence.

Additionally, FOMs 1224 for detecting certain registration changes within, for example, a public switched telephone network 124 can also be used for locating a target MS 140. For example, for some MSs 140 there may be an associated or dedicated device for each such MS that allows the MS to function as a

cordless phone to a line based telephone network when the device detects that the MS is within signaling range. In one use of such a device (also denoted herein as a "home base station"), the device registers with a home location register of the public switched telephone network 124 when there is a status change such as from not detecting the corresponding MS to detecting the MS, or visa versa, as one skilled in the art will understand. Accordingly, by providing a FOM 1224 (denoted the "Home Base Station First Order Model" in Fig. 8(1)) that accesses the MS status in the home location register, the location engine 139 can determine whether the MS is within signaling range of the home base station or not, and generate location hypotheses accordingly.

In one embodiment, such a home base station model may perform the following steps:

(a) Receives an input only from the Public Telephone Switching Network.

(b) If an input is received then the target MS 140 is detected by a home base station associated with the target MS.

(c) If an input is obtained, then the output is a hypothesis data structure having a small area of the highest confidence.

(d) If no input and there is a home base station then a hypothesis having a negative area is of highest confidence is output.

Moreover, other FOMs based on, for example, chaos theory and/or fractal theory are also within the scope of the present invention.

The paragraph beginning on page 54, line 24 has been replaced with the following paragraph:

It is important to note the following aspects of the present invention relating to FOMs 1224:
(28.1) Each such first order model 1224 may be relatively easily incorporated into and/or removed from the present invention. For example, assuming that the signal processing subsystem 1220 provides uniform input interface to the FOMs, and there is a uniform FOM output interface, it is believed that a large majority (if not substantially all) viable MS location estimation strategies may be accommodated. Thus, it is straightforward to add or delete such FOMs 1224.

The paragraph beginning on page 56, line 1 has been replaced with the following paragraph:

(30.2) it enhances the accuracy of an initial location hypothesis generated by [an]a FOM by using the initial location hypothesis as, essentially, a query or index into the location signature data base 1320 for obtaining a corresponding enhanced location hypothesis, wherein the enhanced location hypothesis has

both an adjusted target MS location area estimate and an adjusted confidence based on past performance of the FOM in the location service surrounding the target MS location estimate of the initial location hypothesis;

The paragraph beginning on page 61, line 8 and ending on page 61, line 24 has been replaced with the following paragraph:

A fourth functional group of location engine 139 modules is the control and output gating modules which includes the location center control subsystem 1350, and the output gateway 1356. The location control subsystem 1350 provides the highest level of control and monitoring of the data processing performed by the location center 142. In particular, this subsystem performs the following functions:

(a) controls and monitors location estimating processing for each target MS 140. Note that this includes high level exception or error handling functions;

(b) receives and routes external information as necessary. For instance, this subsystem may receive (via, e.g., the public telephone switching network 124 and Internet [1362]468) such environmental information as increased signal noise in a particular service [are]area due to increase traffic, a change in weather conditions, a base station 122 (or other infrastructure provisioning), change in operation status (e.g., operational to inactive);

(c) receives and directs location processing requests from other location centers 142 (via, e.g., the Internet 468);

(d) performs accounting and billing procedures;

(e)interacts with location center operators by, for example, receiving operator commands and providing output indicative of processing resources being utilized and malfunctions;

(f) provides access to output requirements for various applications requesting location estimates. For example, an Internet 468 location request from a trucking company in Los Angeles to a location center 142 in Denver may only want to know if a particular truck or driver is within the Denver area. Alternatively, a local medical rescue unit is likely to request a precise a location estimate as possible.

The paragraph beginning on page 61, line 25 has been replaced with the following paragraph:

Note that in Fig. 6, (a) - (d) above are, at least at a high level, performed by utilizing the operator interface 1374[ ].

The paragraph beginning on page 61, line 26 has been replaced with the following paragraph:

Referring now to the output gateway 1356, this module routes target MS 140 location estimates to the appropriate location application(s). For instance, upon receiving a location estimate from the most likelihood estimator 1344, the output gateway 1356 may determine that the location estimate is for an automobile being tracked by the police and therefore must be provided [must be provided]according to [the]a particular protocol.

The paragraph beginning on page 63, line 8 has been replaced with the following paragraph:

Taking a CDMA or TDMA base station network as an example, each base station (BS) 122 is required to emit a constant signal-strength pilot channel pseudo-noise (PN) sequence on the forward link channel identified uniquely in the network by a pilot sequence offset and frequency assignment. It is possible to use the pilot channels of the active, candidate, neighboring and remaining sets, maintained in the target MS, for obtaining signal characteristic measurements (e.g., TOA and/or TDOA measurements) between the target MS 140 and the base stations in one or more of these sets.

The paragraph beginning on page 63, line 26 has been replaced with the following paragraph:

Accordingly, some embodiments of distance FOMs may attempt to mitigate such ambiguity or inaccuracies by, e.g., identifying discrepancies (or consistencies) between arrival time measurements and other measurements (e.g., signal strength), these discrepancies (or consistencies) may be used to filter out at least those signal measurements and/or generated location estimates that appear less accurate. In particular, such identifying [may]by filtering can be performed by, for example, an expert system residing in the distance FOM.

The paragraph beginning on page 65, line 1 has been replaced with the following paragraph:

[One]In one embodiment, a coverage area model utilizes both the detection and non-detection of base stations 122 by the target MS 140 (conversely, of the MS by one or more base stations 122) to define an area where the target MS 140 may likely be. A relatively straightforward application of this technique is to:

(a) find all areas of intersection for base station RF coverage area representations, wherein:

(i) the corresponding base stations are on-line for communicating with MSs 140; (ii)

the RF coverage area representations are deemed reliable for the power levels of the on-line base stations; (iii) the on-line base stations having reliable coverage area representations can be detected by the target MS; and (iv) each intersection must include a predetermined number of the reliable RF coverage area representations (e.g., 2 or 3); and

(b) obtain new location estimates by subtracting from each of the areas of intersection any of the reliable RF coverage area representations for base stations 122 that can not be detected by the target MS.

The paragraph beginning on page 66, line 2 has been replaced with the following paragraph:

The stochastic first order models may use statistical prediction techniques such as [ ]principle decomposition, [ ]partial least squares, [partial least squares,]or other regression techniques for predicting, for example, expected minimum and maximum distances of the target MS from one or more base stations 122, e.g., Bollenger Bands. Additionally, some embodiments may use Markov processes and Random Walks (predicted incremental MS movement) for determining an expected area within which the target MS 140 is likely to be. That is, such a process measures the incremental time differences of each pilot as the MS moves for predicting a size of a location area estimate using past MS estimates such as the verified location signatures in the location signature data base 1320.

The paragraph beginning on page 66, line 15 has been replaced with the following paragraph:

Regarding FOMs 1224 using pattern recognition or associativity techniques, there are many such techniques available. For example, there are statistically based systems such as "CART" (an acronym for Classification and Regression Trees) by ANGOSS Software International Limited of Toronto, Canada that may be used for automatically [for]detecting or recognizing patterns in data that were unprovided (and likely previously unknown). Accordingly, by imposing a relatively fine mesh or grid of cells [of]<u>on</u> the radio coverage area, wherein each cell is entirely within a particular area type categorization such as the transmission area types (discussed in the section, "Coverage Area: Area Types And Their Determination" above), the verified location signature clusters within the cells of each area type may be analyzed for signal characteristic patterns. If such patterns are found, then they can be used to identify at least a likely area type in which a target MS is likely to be located. That is, one or more location hypotheses may be generated having target MS 140 location estimates that cover an area having the likely area type wherein the target MS 140 is located. [ ]Further note that such statistically based pattern

recognition systems as "CART" include software code generators for generating expert system software embodiments for recognizing the patterns detected within a training set (e.g., the verified location signature clusters).

The paragraph beginning on page 67, line 1 has been replaced with the following paragraph:

A similar statistically based FOM 1224 to the one above may be provided wherein the radio coverage area is decomposed substantially as above, but in addition to using the signal characteristics for detecting useful signal patterns, the specific identifications of the base station 122 providing the signal characteristics may also be used. Thus, assuming there is a sufficient density of verified location signature clusters in some of the mesh cells so that the statistical pattern recognizer can detect patterns in the signal characteristic measurements, an expert system may be generated that outputs a target MS 140 location estimate that may provide both a reliable and accurate location estimate of a target MS 140.

The paragraph beginning on page 69, line 10 has been replaced with the following paragraph:

It is worthwhile to discuss the data representations for the inputs and outputs of a ANN used for generating MS location estimates. Regarding ANN input representations, recall that the signal processing subsystem 1220 may provide various RF signal measurements as input to an ANN (such as the RF signal measurements derived from verified location signatures in the location signature data base 1320). For example, a representation of a histogram [ ]of the frequency of occurrence of CDMA fingers in a time delay [vs.]versus signal strength 2-dimensional domain may be provided as input to such an ANN. In particular, a 2-dimensional grid of signal strength versus time delay bins may be provided so that received signal measurements are slotted into an appropriate bin of the grid. In one embodiment, such a grid is a six by six array of bins such as illustrated in the left portion of Fig. 14. That is, each of the signal strength and time delay [axises]axes are partitioned into six ranges so that both the signal strength and the time delay of RF signal measurements can be slotted into an appropriate range, thus determining the bin.

The paragraph beginning on page 70, line 10 has been replaced with the following paragraph:

Accordingly, the technique described herein limits the number of input neurons in each ANN constructed and generates a larger number of these smaller ANNs. That is, each ANN is trained on location signature data (or, more precisely, portions of location signature clusters) in an area A_{ANN} (hereinafter also denoted the "net area"), wherein each input neuron receives a unique input from [either]one of:

(A1) location signature data (e.g., signal strength/time delay bin tallies) corresponding to transmissions between an MS 140 and a relatively small number of base stations 122 in the area A_{ANN}. For instance, location signature data obtained from, for example, a collection B of four base stations 122 (or antenna sectors) in the area A_{ANN}., Note, each location signature data cluster includes fields describing the wireless communication devices used; e.g., (i) the make and model of the target MS; (ii) the current and maximum transmission power; (iii) the MS battery power (instantaneous or current); (iv) the base station (sector) current power level; (v) the base station make and model and revision level; (vi) the air interface type and revision level (of, e.g., CDMA, TDMA or AMPS).

The paragraph beginning on page 71, line 7 has been replaced with the following paragraph:

Moreover, [ ]for each of the smaller ANNs, it is likely that the number of input neurons is on the order of 330; (i.e., [ ]70 inputs per each of four location signatures (i.e., 35 inputs for the forward wireless communications and 35 for the reverse wireless communications), plus 40 additional discrete inputs for an appropriate area surrounding A_{ANN}, plus 10 inputs related to: the type of MS, power levels, etc.). However, it is important to note that the number of base stations (or antenna sectors 130) having corresponding location signature data to be provided to such an ANN may vary. Thus, in some subareas of the coverage area 120, location signature data from five or more base stations (antenna sectors) may be used, whereas in other subareas three (or less) may be used.[,]

The paragraph beginning on page 72, line 26 has been replaced with the following paragraph:

In one traditional artificial neural network training process, a relatively tedious set of trial and error steps may be performed for configuring an ANN so that training produces effective learning. In particular, an ANN may require configuring parameters related to, for example, input data scaling, test/training set classification, detecting and removing unnecessary input variable selection. However, the present invention reduces this tedium. That is, the present invention uses mechanisms such as genetic algorithms or other mechanisms for avoiding non-optimal but locally appealing (i.e., local minimum) solutions, and locating near-optimal solutions instead. In particular, such mechanism may be used to adjust the matrix of weights for the ANNs so that very good, near optimal ANN configurations may be found efficiently. [ ]Furthermore, since the signal processing system 1220 uses various types of signal processing filters for filtering the RF measurements received from transmissions between an MS 140 and one or more base stations (antenna sectors 130), such mechanisms for finding near-optimal solutions may be applied to selecting appropriate filters as well. Accordingly, in one embodiment of the present

invention, such filters are paired with particular ANNs so that the location signature data supplied to each ANN is filtered according to a corresponding "filter description" for the ANN, wherein the filter description specifies the filters to be used on location signature data prior to inputting this data to the ANN. In particular, the filter description can define a pipeline of filters having a sequence of filters wherein for each two consecutive filters, f_1 and f_2 (f_1 preceding f_2), in a filter description, the output of f_1 flows as input to f_2. Accordingly, by encoding such a filter description together with its corresponding ANN so that the encoding can be provided to a near optimal solution finding mechanism such as a genetic algorithm, it is believed that enhanced ANN locating performance can be obtained. That is, the combined genetic codes of the filter description and the ANN are manipulated by the genetic algorithm in a search for a satisfactory solution (i.e., location error estimates within a desired range). This process and system provides a mechanism for optimizing not only the artificial neural network architecture, but also identifying a near optimal match between the ANN and one or more signal processing filters. Accordingly, the following filters may be used in a filter pipeline of a filter description: Sobel, median, mean, histogram normalization, input cropping, neighbor, [Gaussion]<u>Gaussian</u>, Weiner filters.

The paragraph beginning on page 79, line 9 has been replaced with the following paragraph. Note the only change herein is the removal of the underlining of the phrase 'there is a "error_rec" here for each loc sig in "loc_sig_bag".'

error_rec_set: A set of error records (objects), denoted "error_recs", providing information as to how much each loc sig in "loc_sig_bag" disagrees with comparable loc sigs in the location signature data base. That is, there is a "error_rec" here for each loc sig in "loc_sig_bag".

The paragraph beginning on page 79, line 22 and ending on page 80, line 9 has been replaced with the following paragraph:

DB_Loc_Sig_Error_Fit(hypothesis, measured_loc_sig_bag, search_criteria)

/* This function determines how well the collection of loc sigs in "measured_loc_sig_bag" fit with the loc sigs in the location signature data base 1320 wherein the data base loc sigs must satisfy the criteria of the input parameter "search_criteria" and are relatively close to the MS location estimate of the location hypothesis, "hypothesis".

Input: hypothesis: MS location hypothesis;

measured_loc_sig_bag: A collection of measured location signatures ("loc sigs" for short) obtained from the MS (the data structure here is an aggregation such as an array or list). Note, it is assumed that there is at most one loc sig here per Base Station in this collection. Additionally, note that the input data structure here may be a location signature cluster such as the "loc_sig_cluster" field of a location hypothesis (cf. Figs. 9A and 9B). Note that variations in input data structures may be accepted here by utilization of flag or tag bits as one skilled in the art will appreciate;

search_criteria: The criteria for searching the verified location signature data base for various categories of loc sigs. The only limitation on the types of categories that may be provided here is that, to be useful, each category should have meaningful number of loc sigs in the location signature data base. The following categories included here are illustrative, but others are contemplated:

(a) "USE ALL LOC SIGS IN DB" (the default),

(b) "USE ONLY REPEATABLE LOC SIGS",

(c) "USE ONLY LOC SIGS WITH SIMILAR TIME OF DAY".

The paragraph beginning on page 80, line 19 has been replaced with the following paragraph:

The following program compares: (a1) loc sigs that are contained in (or derived from) the loc sigs in "target_loc_sig_bag" with (b1) loc sigs computed from verified loc sigs in the location signature data base 1320. That is, each loc sig from (a1) is compared with a corresponding loc sig from (b1) to obtain a measurement of the discrepancy between the two loc sigs. In particular, assuming each of the loc sigs for "target_loc_sig_bag" correspond to the same target MS location, wherein this location is "target_loc", this program determines how well the loc sigs in "target_loc_sig_bag" fit with a computed or estimated loc sig for the location, "target_loc" that is derived from the verified loc sigs in the location signature data base 1320. Thus, this program may be used: (a2) for determining how well the loc sigs in the location signature cluster for a target MS ("target_loc_sig_bag") compares with loc sigs derived from verified location signatures in the location signature data base, and (b2) for determining how consistent a given collection of loc sigs ("target_loc_sig_bag") from the location signature data base is with other loc sigs in the location signature data base. Note that in (b2) each of the one or more loc sigs in "target_loc_sig_bag" have an error computed here that can be used in determining if the loc sig is becoming inapplicable for predicting target MS locations.

The paragraph beginning on page 85, line 5 has been replaced with the following paragraph:

This function creates a new list of location hypotheses from the input list, "loc_hyp_list", wherein the location hypotheses on the new list are modified versions of those on the input list. For each location hypothesis on the input list, one or more corresponding location hypotheses will be on the output list. Such corresponding output location hypotheses will differ from their associated input location hypothesis by one or more of the following: (a) the "image_area" field (see Figs. 9A and 9B) may be assigned an area indicative of where the target MS is estimated to be, (b) if "image_area" is assigned, then the "confidence" field will be the confidence that the target MS is located in the area for "image_area", (c) if there are not sufficient "nearby" verified location signature clusters in the location signature data base 1320 to entirely rely on a computed confidence using such verified location signature clusters, then two location hypotheses (having reduced confidences) will be returned, one having a reduced computed confidence (for "image_area") using the verified clusters in the Location Signature data base, and one being substantially the same as the associated input location hypothesis except that the confidence (for the field "area_est") is reduced to reflect the confidence in its paired location hypothesis having a computed confidence for "image_area". Note also, in some cases, the location hypotheses on the input list, may have no change to its confidence or the area to which the confidence applies.
Get_adjusted_loc_hyp_list_for(loc_hyp)

The paragraph beginning on page 85, line 30 has been replaced with the following paragraph:

[ ]The function, "get_adjusted_loc_hyp_list_for," and functions called by this function presuppose a framework or paradigm that requires some discussion as well as the defining of some terms. Note that some of the terms defined hereinbelow are illustrated in Fig. [243]24.

The paragraph beginning on page 86, line 6 has been replaced with the following paragraph. Note the only change here is the removal of the underlining of the word 'verified.'

Define the term "image cluster set" (for a given First Order Model identified by "loc_hyp.FOM_ID") to mean the set of verified location signature clusters whose MS location point estimates are in "the cluster set".

The paragraph beginning on page 86, line 25 has been replaced with the following paragraph. Note the removal of the underlining in the phrase 'per unit of area.'

Define the term[ ] "mapped cluster density" to be the number of the verified location signature clusters in an "image cluster set" per unit of area in the "image cluster set area".

The paragraph beginning on page 89, line 18 has been replaced with the following paragraph:

(35.5) A location extrapolator module 1432 for use in updating previous location estimates for a target MS when a more recent location hypothesis is provided to the location hypothesis analyzer 1332. That is, assume that the control module 1400 receives a new location hypothesis for a target MS for which there are also one or more previous location hypotheses that either have been recently processed (i.e., they reside in the MS status repository 1338, as shown best in Fig. 6), or are currently being processed (i.e., they reside in the run-time location hypothesis storage area 1410). Accordingly, if the active_timestamp (see Figs. 9A and 9B regarding location hypothesis data fields) of the newly received location hypothesis is sufficiently more recent than the active_timestamp of one of these previous location hypotheses, then an extrapolation may be performed by the location extrapolator module 1432 on such previous location hypotheses so that all target MS location hypotheses being concurrently analyzed are presumed to include target MS location estimates for substantially the same point in time. Thus, initial location estimates generated by the FOMs using different wireless signal measurements, from different signal transmission time intervals, may have their corresponding dependent location hypotheses utilized simultaneously for determining a most likely target MS location estimate. Note that this module may also be daemon or expert system rule base.

Please replace the paragraph beginning on page 100, line 30 through page 101, line 2 with the following paragraph:

Accordingly, if a new currently active location hypothesis (e.g., supplied by the context adjuster) is received by the blackboard, then the target MS location estimate of the new location hypothesis may be compared with the predicted location. Consequently, a confidence adjustment value can be determined according to how well [if] the new location hypothesis "i" fits with the predicted location. That is, this confidence adjustment value will be larger as the new MS estimate and the predicted estimate become closer together.

The paragraph beginning on page 102, line 3 has been replaced with the following paragraph:

Any collection of mobile electronics (denoted mobile location unit) that is able to both estimate a location of a target MS 140 and communicate with the base station network may be utilized by the present

invention to more accurately locate the target MS. Such mobile location units may provide greater target MS location accuracy by, for example, homing in on the target MS and by transmitting additional MS location information to the location center 142. There are a number of embodiments for such a mobile location unit contemplated by the present invention. For example, in a minimal version, such the electronics of the mobile location unit may be little more than an onboard MS 140, a sectored/directional antenna and a controller for communicating between them. Thus, the onboard MS is used to communicate with the location center 142 and possibly the target MS 140, while the antenna monitors signals for homing in on the target MS 140. In an enhanced version of the mobile location unit, a GPS receiver may also be incorporated so that the location of the mobile location unit may be determined and consequently an estimate of the location of the target MS may also be determined. However, such a mobile location unit is unlikely to be able to determine substantially more than a direction of the target MS 140 via the sectored/directional antenna without further base station infrastructure cooperation in, for example, determining the transmission power level of the target MS or varying this power level. Thus, if the target MS or the mobile location unit leaves the coverage area 120 or resides in a poor communication area, it may be difficult to accurately determine where the target MS is located. None-the-less, such mobile location units may be sufficient for many situations, and in fact the present invention contemplates their use. However, in cases where direct communication with the target MS is desired without constant contact with the base station infrastructure, the present invention includes a mobile location unit that is also a scaled down version of a base station 122. Thus, given that such a mobile base station or MBS 148 includes at least an onboard MS 140, a sectored/directional antenna, a GPS receiver, a scaled down base station 122 and sufficient components (including a controller) for integrating the capabilities of these devices, an enhanced autonomous MS mobile location system can be provided that can be effectively used in, for example, emergency vehicles, [air planes]<u>airplanes</u> and boats. Accordingly, the description that follows below describes an embodiment of an MBS 148 having the above mentioned components and capabilities for use in a vehicle.

The paragraph beginning on page 104, line 23 has been replaced with the following paragraph:

Thus, while in the ready state 1708, as the MBS 148 moves, it has its location repeatedly (re)-estimated via, for example, GPS signals, location center [142S]<u>142</u> location estimates from the base stations 122 (and 152), and an on-board deadreckoning subsystem 1527 having an MBS location estimator according to the programs described hereinbelow. However, note that the accuracy of the base

station time synchronization (via the ribidium oscillator 1520) and the accuracy of the MBS 148 location may need to both be periodically recalibrated according to (1a) and (1b) above.

The paragraph beginning on page 106, line 20 has been replaced with the following paragraph:

In one embodiment, the MBS 148 (Fig. 11) includes an MBS controller 1533 for controlling the location capabilities of the MBS 148. In particular, the MBS controller 1533 initiates and controls the MBS state changes as described in Fig. 12 above. Additionally, the MBS controller 1533 also communicates with the location controller 1535, wherein this latter controller controls MBS activities related to MBS location and target MS location; e.g., this performs the program, "mobile_base_station_controller" described in APPENDIX A hereinbelow. The location controller 1535 receives data input from an event generator 1537 for generating event records to be provided to the location controller 1535. For example, [ ]records may be generated from data input received from: (a) the vehicle movement detector 1539 indicating that the MBS 148 has moved at least a predetermined amount and/or has changed direction by at least a predetermined angle, or (b) the MBS signal processing subsystem 1541 indicating that the additional signal measurement data has been received from either the location center 142 or the target MS 140. Note that the MBS signal processing subsystem 1541, in one embodiment, is similar to the signal processing subsystem 1220 of the location center 142. [may have]<u>Moreover, also note that there may be </u>multiple command schedulers. In particular, a scheduler 1528 for commands related to communicating with the location center 142, a scheduler 1530 for commands related to GPS communication (via GPS receiver 1531), a [ ]scheduler 1529 for commands related to the frequency and granularity of the reporting of MBS changes in direction and/or position via the MBS [dead reckoning]<u>deadreckoning </u>subsystem 1527 (note that this scheduler is potentially optional and that such commands may be provided directly to the deadreckoning estimator 1544), and a scheduler 1532 for communicating with the target MS(s) 140 being located. Further, it is assumed that there is sufficient hardware and/or software [to appear]to perform commands in different schedulers substantially concurrently.

The paragraph beginning on page 109, line 32 has been replaced with the following paragraph:

It is assumed that the error with [dead reckoning]<u>deadreckoning </u>increases with deadreckoning distance. Accordingly, it is an aspect of the embodiment of the MBS location subsystem 1508 that when incrementally updating the location of the MBS 148 using deadreckoning and applying deadreckoning location change estimates to a "most likely area" in which the MBS 148 is believed to be, this area is

incrementally enlarged as well as shifted. The enlargement of the area is used to account for the inaccuracy in the deadreckoning capability. Note, however, that the deadreckoning [ ]MBS location estimator is periodically reset so that the error accumulation in its outputs can be decreased. In particular, such resetting occurs when there is a high probability that the location of the MBS is known. For example, the deadreckoning MBS location estimator may be reset when an MBS operator manually enters an MBS location or verifies an MBS location, or a computed MBS location has sufficiently high confidence.

The paragraph beginning on page 110, line 32 has been replaced with the following paragraph:

Further, the MBS 148 may constrain any location estimates to streets on a street map using the MBS location snap to street module 1562. For example, an estimated MBS location not on a street may be "snapped to" a nearest street location. Note that a nearest street location determiner may use "normal" orientations of vehicles on streets as a constraint on the nearest street location, p[. P]articularly, if an MBS 148 is moving at typical rates of speed and acceleration, and without abrupt changes in direction. For example, if the deadreckoning MBS location estimator 1544 indicates that the MBS 148 is moving in a northerly direction, then the street snapped to should be a north-south running street. Moreover, the MBS location snap to street module 1562 may also be used to enhance target MS location estimates when, for example, it is known or suspected that the target MS 140 is in a vehicle and the vehicle is moving at typical rates of speed. Furthermore, the snap to street location module 1562 may also be used in enhancing the location of a target MS 140 by either the MBS 148 or by the location engine 139. In particular, the location estimator 1344 or an additional module between the location estimator 1344 and the output gateway 1356 may utilize an embodiment of the snap to street location module 1562 to enhance the accuracy of target MS 140 location estimates that are known to be in vehicles. Note that this may be especially useful in locating stolen vehicles that have embedded wireless location transceivers (MSs 140), wherein appropriate wireless signal measurements can be provided to the location center 142.

The paragraph beginning on page 111, line 29 has been replaced with the following paragraph:

There is an MBS location track for storing MBS location entries obtained from MBS location estimation information from each of the MBS baseline location estimators described above (i.e., a GPS location track 1750 for storing MBS location estimations obtained from the GPS location estimator 1540, a location center location track 1754 for storing MBS location estimations obtained from the location estimator 1540 deriving its MBS location estimates from the location center 142, an LBS location track

1758 for storing MBS location estimations obtained from the location estimator 1540 deriving its MBS location estimates from base stations 122 and/or 152, and a manual location track 1762 for MBS operator entered MBS locations). Additionally, there is one further location track, denoted the "current location track" 1766 whose location track entries may be derived from the entries in the other location tracks (described further hereinbelow). Further, for each location track, there is a location track head that is the head of the queue for the location track. The location track head is the most recent (and presumably the most accurate) MBS location estimate residing in the location track. Thus, [for]the GPS location track 1750 has location track head 1770; the location center location track 1754 has location track head 1774; the LBS location track 1758 has location track head 1778; the manual location track 1762 has location track head 1782; and the current location track 1766 has location track head 1786. Additionally, for notational convenience, for each location track, the time series of previous MBS location estimations (i.e., location track entries) in the location track will herein be denoted the "path for the location track." Such paths are typically the length of the location track queue containing the path. Note that the length of each such queue may be determined using at least the following considerations:

The paragraph beginning on page 115, line 15 and ending on page 115, line 18 has been replaced with the following paragraph:

MBS_new_est <--- *get_new_MBS_location_using_estimate*(event);

/* Note, whenever a new MBS location estimate is entered as a baseline estimate into <u>one of</u> the location tracks, the other location tracks must be immediately updated with any deadreckoning location change estimates so that all location tracks are substantially updated at the same time. */

The paragraph beginning on page 120, line 19 has been replaced with the following paragraph:

/* This information includes error or reliability estimates that may be used in subsequent attempts to determine an [MBS]<u>MS</u> location estimate when there is no communication with the LC and no exact (GPS) location can be obtained. That is, if the reliability of the target MS's location is deemed highly reliable, then subsequent less reliable location estimates should be used only to the degree that more highly reliable estimates become less relevant due to the [MBS]<u>MS</u> moving to other locations. */

The paragraph beginning on page 122, line 28 has been replaced with the following paragraph. Note the only change here is the insertion of --)-- immediately after "events."

MBS_new_est <--- *get_new_MBS_location_est_from_operator*(event); /* The estimate may be obtained, for example, using a light pen on a displayed map */

The paragraph beginning on page 124, line 1 and ending on page 124, line 12 has been replaced with the following paragraph:

The confidence value for each MBS location estimate is a measurement of the likelihood of the MBS location estimate being correct. More precisely, a confidence value for a new MBS location estimate is a measurement that is adjusted according to the following criteria:

(a) the confidence value increases with the perceived accuracy of the new MBS location estimate (independent of any current MBS location estimate used by the MBS),

(b) the confidence value decreases as the location discrepancy with the current MBS location increases,

(c) the confidence value for the current MBS location increases when the new location estimate is contained in the current location estimate,

(d) the confidence value for the current MBS location [decrease]<u>decreases</u> when the new location estimate is not contained in the current location estimate, and

Therefore, the confidence value is an MBS location likelihood measurement which takes into account the history of previous MBS location estimates.

The paragraph beginning on page 132, line 27 and ending on page 132, line 31 has been replaced with the following paragraph. Note inserted text has been *italicized*, since there is underlining as part of the text.

Input:	**MBS_new_est**	The newest MBS location estimate record.
	adjusted_curr_est	The version of "MBS_curr_est" adjusted by the deadreckoning location change estimate paired with "MBS_new_est". .
	MBS_curr_est	The location track entry that is the head of the "current" location track. Note that "MBS_new_est.confidence" > "MBS_curr_[est.cofidence]*est.confidence*".

The paragraph beginning on page 143, line 14 and ending on page 143, line 19 has been replaced with the following paragraph:

measured_loc_sig_bag: A collection of measured location signatures ("loc sigs" for short) obtained from the MS (the data structure here is an aggregation such as an array or list). Note, it is assumed that there is at most one loc sig here per Base Station in this collection. Additionally, note that the input data structure here may be a location signature cluster such as the "loc_sig_cluster" field of a location hypothesis (cf. Figs. 9A and 9B). Note that variations in input data structures may be accepted here by utilization of flag or tag bits as one skilled in the art will appreciate;

The paragraph beginning on page 147, line 28 has been replaced with the following paragraph. Note the only change herein is the removal of the underlining of the phrase '*there is an "error_rec" here for each loc sig in "loc_sig_bag".*'. Note the change is in bold rather than underlined.

error_rec_set: The set of "error_recs" providing information as to how much each loc sig in "loc_sig_bag" disagrees with comparable loc sigs in the DB. That is, ***there is an "error_rec" here for each loc sig in "loc_sig_bag".***

The paragraph beginning on page 161, line 9 has been replaced with the following paragraph. Note the only change is the replacement of "Fig. 9" with –Figs. 9A and 9B–.

This function creates a new list of location hypotheses from the input list, "loc_hyp_list", wherein the location hypotheses on the new list are modified versions of those on the input list. For each location hypothesis on the input list, one or more corresponding location hypotheses will be on the output list. Such corresponding output location hypotheses will differ from their associated input location hypothesis by one or more of the following: (a) the "image_area" field (see Figs. 9A and 9B) may be assigned an area indicative of where the target MS is estimated to be, (b) if "image_area" is assigned, then the "confidence" field will be the confidence that the target MS is located in the area for "image_area", (c) if there are not sufficient "nearby" verified location signature clusters in the location signature data base to entirely rely on a computed confidence using such verified location signature clusters, then two location hypotheses (having reduced confidences) will be returned, one having a reduced computed confidence (for "image_area") using the verified clusters in the Location Signature DB, and one being substantially

the same as the associated input location hypothesis except that the confidence (for the field "area_est") is reduced to reflect the confidence in its paired location hypothesis having a computed confidence for "image_area". Note also, in some cases, the location hypotheses on the input list, may have no change to its confidence or the area to which the confidence applies. Note that the steps herein are also provided in flowchart form in Figs. 25a and 25b.

The paragraph beginning on page 161, line 29 and ending on page 162, line 6 has been replaced with the following paragraph. Note the only change is the replacement of "Mobil" with –Mobile–.

if (NOT loc_hyp[i].adjust) then /* no adjustments will be made to the "area_est" or the "confidence" fields since the "adjust" field indicates that there is assurance that these other fields are correct; note that such designations indicating that no adjustment are presently contemplated are only for the location hypotheses generated by the Home Base Station First Order Model, the Location Base Station First Order Model and the Mobile Base Station First Order Model. In particular, location hypotheses from the Home Base Station model will have confidences of 1.0 indicating with highest confidence that the target MS is within the area estimate for the location hypothesis. Alternatively, in the Location Base Station model, generated location hypotheses may have confidences of (substantially) +1.0 (indicating that the target MS is absolutely in the area for "area_est"), or, -1.0 (indicating that the target MS is NOT in the area estimate for the generated location hypothesis).*/

The paragraph beginning on page 162, line 10 has been replaced with the following paragraph. Note the only change here is the replacement of "FIG. 9" with –Figs. 9A and 9B–.

else /* the location hypothesis can (and will) be modified; in particular, an "image_area" may be assigned, the "confidence" changed to reflect a confidence in the target MS being in the "image_area". Additionally, in some cases, more than one location hypothesis may be generated from "loc_hyp[i]". See the comments on [FIG. 9]<u>Figs. 9A and 9B</u> and the comments for "get_adjusted_loc_hyp_list_for" for a description of the terms here. */

The paragraph beginning on page 163, line 8 has been replaced with the following paragraph. Please note that the only change is the removal of underlining of text of the word –verified–.

Define the term "**image cluster set**" (for a given First Order Model identified by "loc_hyp.FOM_ID") to mean the set of verified location signature clusters whose MS location point estimates are in "the cluster set".

The paragraph beginning on page 164, line 1 has been replaced with the following paragraph. Note the only change herein is the removal of the underlining in the phrase 'identifier may also be dependent on the area type.' This phrase is identified in bold hereinbelow.

pt_max_area <--- *get_max_area_surrounding_pt*(loc_hyp, mesh); /* Get the maximum area about "pt_est" that is deemed worthwhile for examining the behavior of the "loc_hyp.FOM_ID" First Order Model (FOM) about "pt_est". Note that in at least one embodiment, this value of this **identifier may also be dependent on the area type** within which "loc_hyp.pt_est" resides. Further, this function may provide values according to an algorithm allowing periodic tuning or adjusting of the values output, via, e.g., a Monte Carlo simulation (more generally, a statistical simulation or regression) or a Genetic Algorithm. In some embodiments of the present invention, the value determined here may be a relatively large proportion of the entire radio coverage area region. However, the tuning process may be used to shrink this value for (for example) various area types as location signature clusters for verified MS location estimates are accumulated in the location signature data base. */

The paragraph beginning on page 164, line 10 has been replaced with the following paragraph. Note the removal of the underlining in the phrase 'vary according to area type and/or area size (of "area")'. This phrase is identified by bold rather than underlining below.

min_clusters <--- *get_min_nbr_of_clusters*(loc_hyp.FOM_ID, area); /* For the area, "area", get the minimum number ("min_clusters") of archived MS estimates, L, desired in generating a new target MS location estimate and a related confidence, wherein this minimum number is likely to provide a high probability that this new target MS location estimate and a related confidence are meaningful enough to use in subsequent Location Center processing for outputting a target MS location estimate.

More precisely, this minimum number, "min_clusters," is an estimate of the archived MS location estimates, L, required to provide the above mentioned high probability wherein each L satisfies the following conditions: (a) L is in the area for "area"; (b) L is archived in the location signature data base; (c) L has a corresponding verified location signature cluster in the location signature data base; and (d) L is generated by the FOM identified by "loc_hyp.FOM_ID"). In one embodiment, "min_clusters" may be a constant; however, in another it may vary **according to area type and/or area size (of "area")**, in some it may also vary according to the FOM indicated by "loc_hyp.FOM_ID". */

The paragraph beginning on page 168, line 15 has been replaced with the following paragraph. Note the only change is the removal of underlining from –per unit of area–.

Define the term **"mapped cluster density"** to be the number of the verified location signature clusters in an "image cluster set" per unit of area in the "image cluster set area".

The paragraph beginning on page 170, line 1 has been replaced with the following paragraph. Note the only change herein is the removal of the underlining in the phrase '*positive* confidence.' This phrase is identified by bold rather than underlining below.

/* Given the above two values, a ***positive* confidence** value for the area, "image_area", can be calculated based on empirical data.

The paragraph beginning on page 171, line 3 has been replaced with the following paragraph. Note there are square brackets that do not denote deletions herein. Square brackets denoting deletions are in 16 point font and in bold.

Note that the product of [CA1.1] and [CA1.2] provide the above desired characteristics for calculating the confidence. However, there is no guarantee that the range of resulting values from such products is consistent with the interpretation that has been placed on (positive) confidence values; e.g., that a confidence of near 1.0 has a very high likelihood that the target MS is in the corresponding area. For example, it can be that this product rarely is greater than 0.8, even in the areas of highest confidence. Accordingly, a "tuning" function is contemplated which provides an additional factor for adjusting of the confidence. This factor is, for example, a function of the area types and the size of each area type in

"image_area"[ ]. Moreover, such a tuning function may be dependent on a "tuning coefficient" per area type. Thus, one such tuning function may be:

$$\mathbf{min}([S]\sum_{i=1}^{\text{number of area types}} [tc_i * \text{sizeof(area type}_i \text{ in "image\_area") / sizeof ("image\_area")}], 1.0)$$

where tc_i is a tuning coefficient (determined in background or off-line processing; e.g., by a Genetic Algorithm or Monte Carlo simulation or regression) for the area type indexed by "i".